Hi! This presentation will give you an overview of our study currently under review in HESS
doi.org/10.5194/hess-2019-652

Discuss and chat with us on Monday 4.5.2020 at 10:45!

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Why does a conceptual hydrological model fail to correctly simulate observed discharge changes in response to climatic changes?

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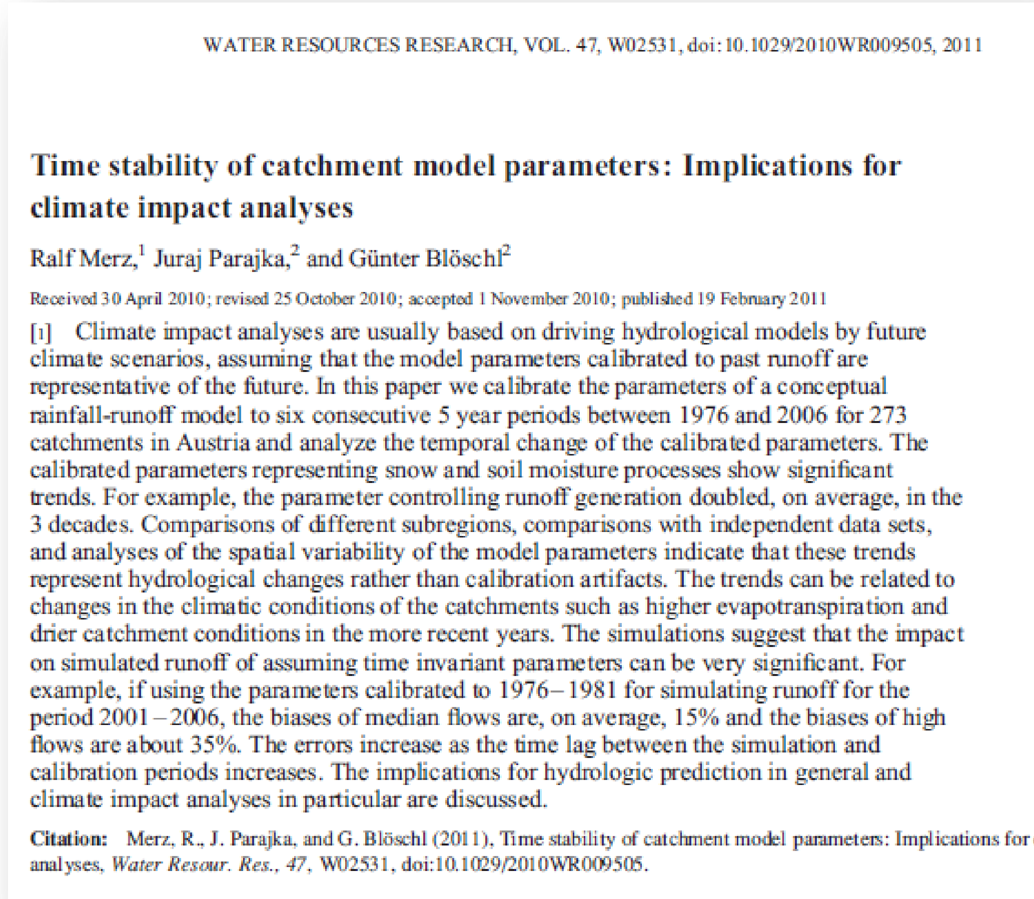
Motivation

The background is a study of Merz et al. on hydrological modeling in a transient climate for 273 catchments in Austria.

What they did:

- Model calibration in 1976-81
- Simulation of 1976-2006, where preci-pitation and temperature increased.

They found: a simulated discharge increase while the observations show no trend.


WATER RESOURCES RESEARCH, VOL. 47, W02531, doi:10.1029/2010WR009505, 2011

Time stability of catchment model parameters: Implications for climate impact analyses

Ralf Merz,[1] Juraj Parajka,[2] and Günter Blöschl[2]

Received 30 April 2010; revised 25 October 2010; accepted 1 November 2010; published 19 February 2011

[1] Climate impact analyses are usually based on driving hydrological models by future climate scenarios, assuming that the model parameters calibrated to past runoff are representative of the future. In this paper we calibrate the parameters of a conceptual rainfall-runoff model to six consecutive 5 year periods between 1976 and 2006 for 273 catchments in Austria and analyze the temporal change of the calibrated parameters. The calibrated parameters representing snow and soil moisture processes show significant trends. For example, the parameter controlling runoff generation doubled, on average, in the 3 decades. Comparisons of different subregions, comparisons with independent data sets, and analyses of the spatial variability of the model parameters indicate that these trends represent hydrological changes rather than calibration artifacts. The trends can be related to changes in the climatic conditions of the catchments such as higher evapotranspiration and drier catchment conditions in the more recent years. The simulations suggest that the impact on simulated runoff of assuming time invariant parameters can be very significant. For example, if using the parameters calibrated to 1976–1981 for simulating runoff for the period 2001–2006, the biases of median flows are, on average, 15% and the biases of high flows are about 35%. The errors increase as the time lag between the simulation and calibration periods increases. The implications for hydrologic prediction in general and climate impact analyses in particular are discussed.

Citation: Merz, R., J. Parajka, and G. Blöschl (2011), Time stability of catchment model parameters: Implications for c analyses, *Water Resour. Res.*, *47*, W02531, doi:10.1029/2010WR009505.

Motivation

Several other studies show similar problems (but not in all cases).

Are current hydrological models suitable for climate change assessments?

To improve hydrological modeling under climate change, we first need to know the causes of these problems.

Our aim was therefore to revisit the study by Merz et al. (2011) and find out about the causes of the problem.

WATER RESOURCES RESEARCH, VOL. 48, W05552, doi:10.1029/2011WR011721, 2012

Crash testing hydrological models in contrasted climate conditions: An experiment on 216 Australian catchments

L. Coron,[1,2] V. Andréassian,[2] C. Perrin,[2] J. Lerat,[3] J. Vaze,[3] M. Bourqui,[1] and F. Hendrickx[1]

Hydrol. Earth Syst. Sci., 16, 1171–1189, 2012
www.hydrol-earth-syst-sci.net/16/1171/2012/
doi:10.5194/hess-16-1171-2012
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Hydrology and Earth System Sciences

Multimodel evaluation of twenty lumped hydrological models under contrasted climate conditions

G. Seiller[1], F. Anctil[1], and C. Perrin[2]

Journal of Hydrology 394 (2010) 447–457

Contents lists available at ScienceDirect

Journal of Hydrology

journal homepage: www.elsevier.com/locate/jhydrol

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Climate non-stationarity – Validity of calibrated rainfall–runoff models for use in climate change studies

HYDROLOGICAL SCIENCES JOURNAL
2018, VOL. 63, NO. 7, 991–1007
https://doi.org/10.1080/02626667.2018.1466056

Taylor & Francis

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Hydrological model parameter (in)stability – "crash testing" the HBV model under contrasting flood seasonality conditions

Klaus Vormoor[a], Maik Heistermann[a], Axel Bronstert[a] and Deborah Lawrence[b]

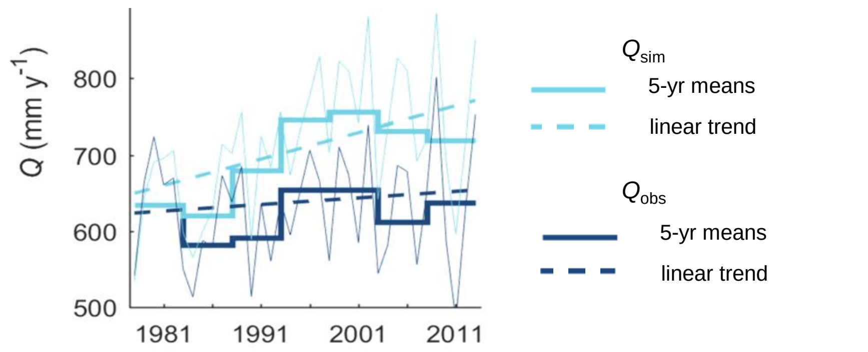
Revisiting the study by Merz et al. (2011): Differences between simulated and observed discharge changes

Methods

- Hydrological model: HBV, semi-distributed
- 156 catchments without glaciers, changes in flow diversions, data gaps
- Automatic calibration in 1978-1982 and simulation for 1978-2013

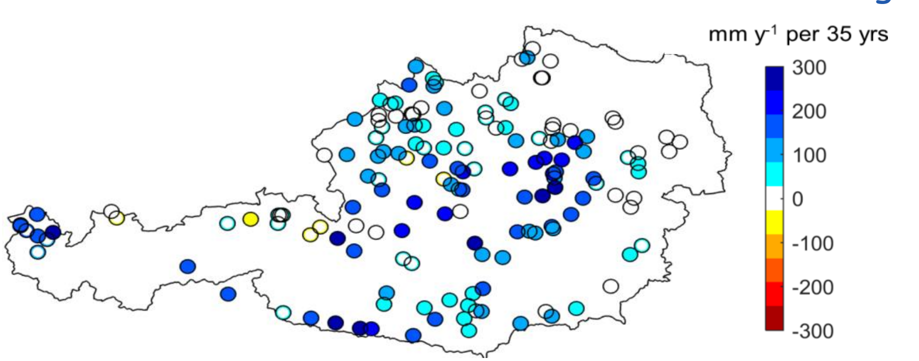
The gap between trends in Q_{sim} and Q_{obs} is 92 ± 50 mm yr^{-1} over the 35-year period, on average over all catchments.

Discharge variations averaged over all catchments



The problem occurs in many catchments spread all over Austria.

Difference between trends in sim. and obs. discharge



Duethmann et al., 2020, Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2019-652

Possible causes of the problem

We set up hypotheses for the possible causes. Some could be classified as unlikely after literature research or based on process understanding.

For example, rating curve errors are unlikely to occur in the same direction for a large number of catchments. This is therefore unlikely a relevant cause for a large number of catchments.

We evaluated the other hypotheses with modifications of the model (examples on the next slides).

Working hypothesis
(1) Data problems
Problems in the discharge data
Changes in abstractions or diversions
Rating curve errors
Problems in the precipitation data
Inhomogeneities in the precipitation data due to instrument changes
Inhomogeneities in the gridded precipitation data due to changes in the number of stations
Biased estimates of the precipitation trend due to changes in the catch ratio caused by changes in the snow-to-rain ratio and changes in precipitation intensities
Problems in the air temperature data
Inhomogeneities in the gridded air temperature data due to changes in the number of stations
(2) Problems related to the model calibration
Too short calibration period
Objective function insensitive to long-term discharge variations
Internal inconsistencies due to calibration only to discharge
(3) Problems of the model structure
Effects of changes in radiation and saturation deficit not reflected by the model
Effects of changes in the vegetation dynamics and land cover not reflected by the model

Duethmann et al., 2020, Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2019-652

Hypotheses related to the model calibration

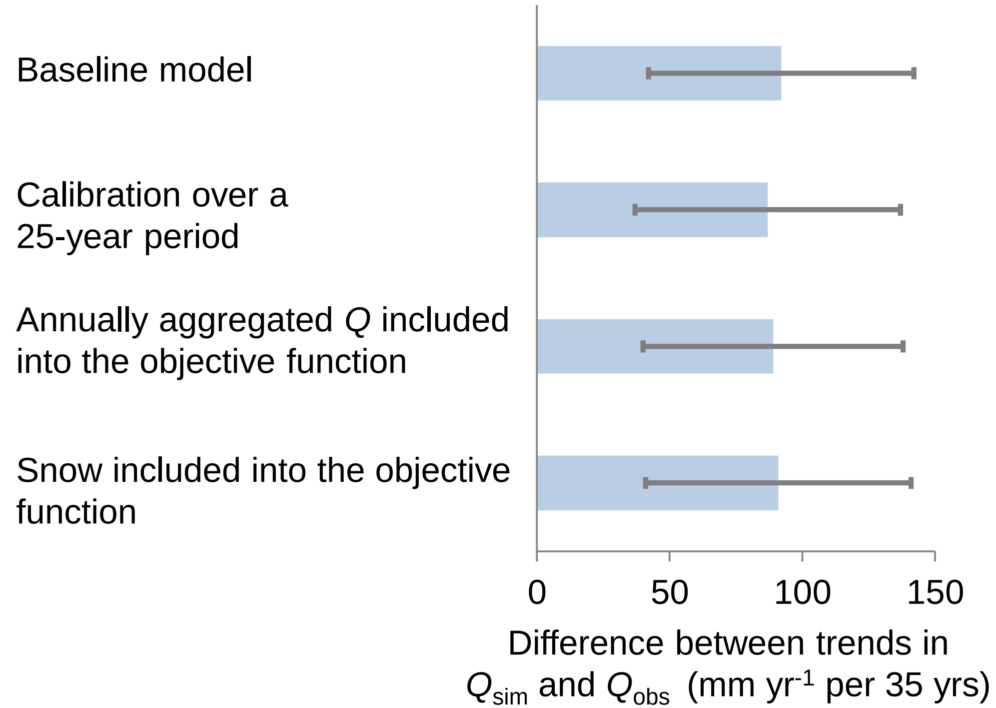
"A 5-year calibration period is too short."

"When calibrating to daily discharge values, the sensitivity to long-term changes is too low."

"Calibrating only to discharge is not enough."

These hypotheses are evaluated using modifications of the model … but none of them reduces the problem significantly.

Effect of model modifications on the gap between trends of simulated and observed discharge



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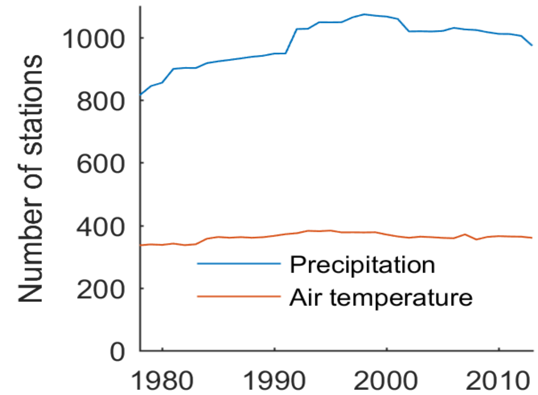
Hypotheses related to data problems

A possible problem are inhomogeneities in the input data. A varying number of gauges included for generating the gridded data sets would affect many catchments.

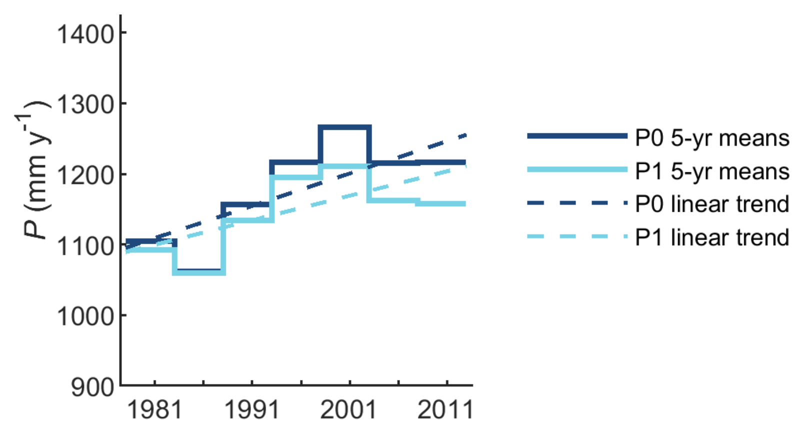
Modification: use a precipitation data set based on a constant number of stations (instead of using all available stations as in Merz2011).

This reduces the gap between trends in Q_{sim} and Q_{obs} by 37 ± 26 mm yr^{-1} over the 35-year period.

Number of stations included for the gridded climate data sets used in the baseline model



Precipitation changes averaged over all catchments

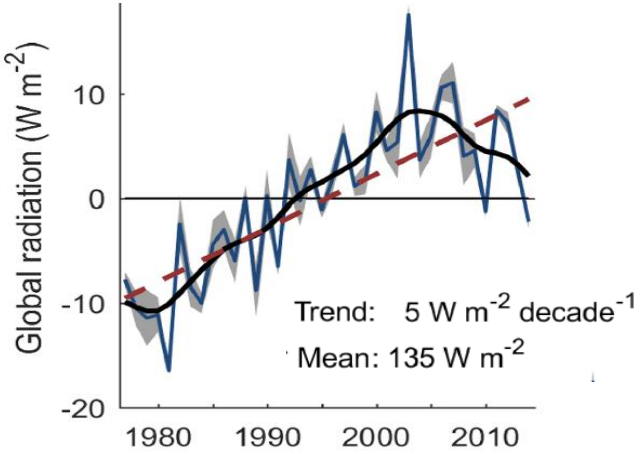


Duethmann et al., 2020, Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2019-652

Model structural problems

The Blaney-Criddle approach applied for calculating E_{ref} cannot take into account changes in other climate variables than air temperature (e.g. the increase in radiation).

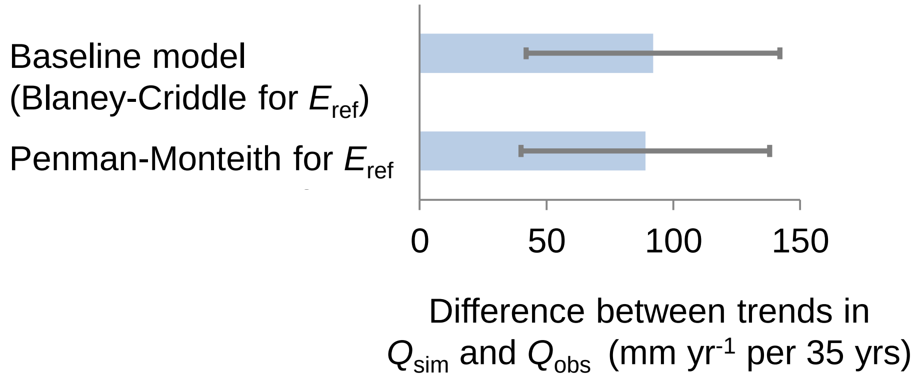
Changes in global radiation



Duethmann D, Blöschl G, Hydrol. Earth Syst. Sci., 2018
https://doi.org/10.5194/hess-22-5143-2018.

Using a more physically based approach for E_{ref} does not significantly reduce the problem.

Effect of model modifications on the gap between trends of simulated and observed discharge



Duethmann et al., 2020, Hydrol. Earth Syst. Sci. Discuss.

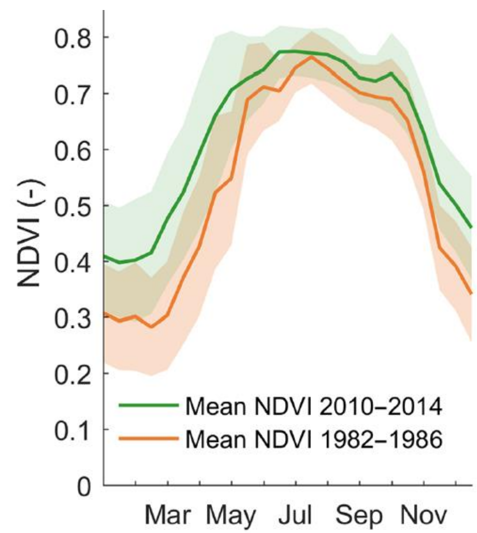
Model structural problems: effects of vegetation "greening"

Changes in vegetation dynamics, such as a longer vegetation period, are not considered by the HBV model.

Modification: Consider changes in surface resistance based on a satellite-based vegetation index (NDVI data from AVHRR) for the calculation of E_{ref}.

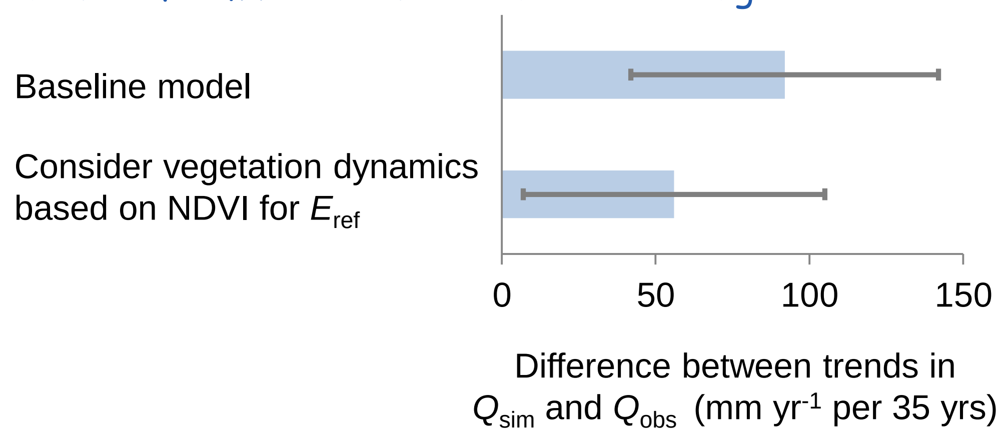
This reduces the gap between trends in Q_{sim} and Q_{obs} by 35 ± 9 mm yr^{-1} over the 35-year period.

Changes in NDVI



Duethmann D, Blöschl G, Hydrol. Earth Syst. Sci., 2018
https://doi.org/10.5194/hess-22-5143-2018.

Effect of model modifications on the gap between trends of simulated and observed discharge



Duethmann et al., 2020, Hydrol. Earth Syst. Sci. Discuss.

Conclusions and implications

For climate impact analyses, we need approaches that can consider changes in vegetation dynamics (most conceptual hydrological models don't do this!).

When studying long-term dynamics, it is very important to use climate data based on a constant number of stations.

We need further studies on the causes of poor (and good) performance of hydrological models in transient climate conditions to get a more complete picture on in what cases what model structure components and what parameterization methods result in poor model performance in a changing climate.

Ultimately, this will increase the robustness of hydrologic simulations in a changing climate.

Duethmann et al., 2020, Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2019-652

Discuss with us!

What are your experiences with hydrological modelling under changing climate conditions?

Should we avoid conceptual hydrological models in climate change impact analyses?

What causes did you find for problems of simulating long-term dynamics in a changing climate?

Are you working on this topic and interested in further discussion and exchange of experiences?

See you and chat with us on Monday 4.5.2020 at 10:45!

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 Duethmann et al., 2020, Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2019-652